

TITLE OF THE INVENTION

CHUCK EQUIPMENT

BACKGROUND OF THE INVENTION

5 1. Field of the Invention

The present invention relates to chuck equipments and more particularly to a chuck equipment which can hold insulating substrates.

2. Description of the Related Art

10 Conventionally, electrostatic chuck equipments have been used to hold substrates in vacuum apparatuses.

A sputtering apparatus, generally denoted at reference numeral 101 in Fig.9(a), has a vacuum chamber 110. On the top side ceiling of the vacuum chamber 110, there is arranged a target 102. On the bottom wall side, there is
15 arranged a chuck equipment 104.

The chuck equipment 104 comprises a dielectric layer 121 and a pair of electrodes 122₁, 122₂ embedded in said dielectric layer 121. The chuck equipment 104 also has
20 holes, formed in the dielectric layer 121, and lift pins 106 are inserted into the holes from below.

The electrodes 122₁, 122₂ are each connected to a chuck equipment power supply 109 which is arranged outside the vacuum chamber 110.

25 When a substrate 112 is placed on the chuck equipment

104, the substrate 112 opposes in parallel to each of the
electrodes 122₁, 122₂ via the dielectric layer 121, having
a thickness of several tens to several hundreds of
micrometers disposed between the substrate 112 and the
5 electrodes 122₁, 122₂.

The substrate 112 such as a silicon or gallium
arsenide wafer is electrical conductive. Therefore, when
the substrate 112 is placed on the chuck equipment 104, and
followed by the power supply 109 turned on, there will be
10 formed a capacitor, designated at reference numeral 125₁ in
Fig.9(b), between one of the electrodes 122₁ and the
substrate 112. There will also be formed another capacitor,
designated at reference numeral 125₂ in Fig.9(b), between
the other one of the electrodes 122₂ and the substrate 112.

15 These two capacitors 125₁, 125₂ are connected to the
power supply 109 in series with each other. Application of
a positive voltage to the one electrode 122₁ and a negative
voltage to the other electrode 122₂ would allow the
capacitors 125₁, 125₂ to be electrically charged. This will
20 cause an electrostatic pressure to be generated between the
substrate 112 and the one electrode 122₁ and between the
substrate 112 and the other electrode 122₂. The
electrostatic attraction thus generated clamps the
substrate 112 electrostatically on the surface of the chuck
25 equipment 104.

However, it has been lately wanted to perform vacuum processing on glass substrates which constitute liquid crystal display devices or plasma display devices while the glass substrate is being electrostatically clamped on the chuck equipment.

Semiconductor substrates formed of a single crystal have electrical conductivity even with a high resistance, thus making it possible to generate an electrostatic pressure for clamping the substrate on the chuck equipment. However, glass substrates have too high insulation to form the capacitors shown in Fig.9(b), thereby allowing the substrate not to be electrostatically clamped on the chuck equipment 104.

SUMMARY OF THE INVENTION

The present invention was developed to solve the aforementioned prior-art problems and an object thereof is to provide a chuck equipment which can hold insulating substrates.

The present invention is a chuck equipment comprising a plate-shaped base, a first electrode to which a first voltage is applied, and a second electrode to which a second voltage different from said first voltage in magnitude is applied, the first and second electrodes being insulated from each other and arranged on a surface of the

base.

The present invention is the chuck equipment, in which surfaces of the first and second electrodes can be exposed.

5 The chuck equipment of the present invention is constructed in such a manner that a substrate may be placed on the surface of the chuck equipment on which the first and second electrodes are arranged to cause the substrate to be brought into contact with the first and second
10 electrodes.

The chuck equipment of the present invention is characterized in that the surface of the base is even with the surfaces of the first and second electrodes.

According to the chuck equipment of the present
15 invention, an insulating convexity portion can be arranged between the first and second electrodes.

According to the chuck equipment of the present invention, the first and second electrodes can have a protective film arranged on the surfaces thereof.

20 The chuck equipment of the present invention may be constructed in such a manner that a substrate may be placed on the surface of the chuck equipment on which the first and second electrodes are arranged to cause the substrate to be brought into contact with the protective film formed
25 on the first and second electrodes.

According to the chuck equipment of the present invention, the first electrode can be spaced apart from the second electrode by 2mm or less.

According to the chuck equipment of the present invention, the first and second electrodes can be made 4mm or less in width.

The chuck equipment according to the present invention may comprise a plurality of the first and second electrodes arranged thereon, and regions where the first and second electrodes are alternately arranged.

The chuck equipment according to the present invention may have a third electrode to which a third voltage different from first and second voltages is applied.

Furthermore, the present invention also provides a vacuum processing apparatus comprising a vacuum chamber in which the above-described chuck equipment of the present invention is arranged.

The vacuum processing apparatus according to the present invention may comprise a power supply for establishing an electric field of $1.0 \times 10^6 \text{V/m}$ or greater between the first and second electrodes.

According to the vacuum processing apparatus of the present invention, a protective plate may be arranged around the chuck equipment, and a substrate may be placed on the chuck equipment to cause the substrate to be

accommodated in the protective plate.

BRIEF DESCRIPTION OF DRAWINGS

Fig.1(a) is a view illustrating a vacuum processing
5 apparatus according to an embodiment of the present
invention; and Fig.1(b) is an enlarged view illustrating
part of a chuck equipment according to the present
invention.

Fig.2(a) is a view illustrating the arrangement of
10 electrodes of the chuck equipment according to a first
embodiment of the present invention; and Fig.2(b) is a
cross-sectional view of the chuck equipment.

Fig.3(a) is a schematic cross-sectional view
illustrating the chuck equipment according to the first
15 embodiment of the present invention; Fig.3(b) is a
schematic cross-sectional view illustrating a chuck
equipment according to a second embodiment of the present
invention; Fig.3(c) is a schematic cross-sectional view
illustrating a chuck equipment according to a third
20 embodiment of the present invention; and Fig.3(d) is a
schematic cross-sectional view illustrating a chuck
equipment according to a fourth embodiment of the present
invention.

Fig.4(a) is a cross-sectional view illustrating a
25 chuck equipment in which an insulating protective film is

formed on the surface of the chuck equipment according to
the first embodiment of the present invention; Fig.4(b) is
a cross-sectional view illustrating a chuck equipment in
which a conductive protective film is formed on the surface
5 of and around the first and second electrodes of the chuck
equipment according to the first embodiment of the present
invention; and Fig.4(c) is a cross-sectional view
illustrating a chuck equipment in which a conductive
protective film is arranged on the surface of a chuck
10 equipment according to the fourth embodiment of the present
invention.

Fig.5 is an explanatory view illustrating the
electrostatic pressure of the chuck equipment according to
the present invention.

15 Figs.6(a) to 6(c) are views illustrating embodiments
of electrode arrangements employed by the chuck equipment
according to the present invention.

Figs.7(d) and 7(e) are views illustrating other
embodiments of electrode arrangements employed by the chuck
20 equipment according to the present invention.

Fig.8 is an explanatory view illustrating the
gradient force.

Figs.9(a) and 9(b) are explanatory views illustrating
a prior art chuck equipment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As described above, since the prior-art chuck equipment electrostatically holds substrates such as silicon wafers having electrical conductivity, an insulating material with a high dielectric constant such as Al_2O_3 , AlN , SiC , polyimide, or silicone rubber is disposed between the electrodes and the substrate (otherwise, the electrodes would be short-circuited therebetween without the insulating materials).

Accordingly, between the substrate and the electrodes, the capacitors are formed to cause Coulombic forces to be developed. A electrostatic pressure F developed by the Coulombic force per unit area can be expressed by the following equation.

$$F = 1/2 \cdot a \cdot (V/d)^2$$

where "a" is a coefficient dependent on the dielectric constant and surface condition of the insulating material, "d" is the distance between the substrate and an electrode (which, in more detail, means the thickness of the insulating material or the gap between the substrate and the surface of the electrostatic chuck equipment), and "V" is the voltage applied between the electrode and the substrate.

However, with an insulating substrate such as a piece of glass, no capacitor is formed between the substrate and

the electrodes, thus creating no electrostatic
electrostatic pressure F developed by the aforementioned
Coulombic force.

On the other hand, it is known that an insulating
substance of polarizability α being placed in an electric
field E is acted upon by a gradient force f per unit volume
as follows.

$$f = 1/2 \cdot \alpha \cdot \text{grad}(E^2)$$

The inventors of the present invention focused
attention on the gradient force f, thereby leading to the
invention of a chuck equipment which was able to hold even
insulating substrates.

In the foregoing, it holds for the dielectric
(insulating substances) that $\alpha > 0$. According to the above
equation, the insulating substrate is therefore to be
attracted toward a stronger electric field.

Referring to Fig.8, reference numeral 80 designates
an electric field established between electrodes 81 and 82,
to which a positive and negative voltage is applied with
respect to a substrate 83. The electric field is stronger
in the vicinity of electrodes 81, 82 and weaker away from
them, thus causing a force f to act upon the substrate 83
toward the electrodes 81, 82.

Furthermore, according to the above equation, a
greater gradient force f acts on the substrate having a

greater grad (E^2). Thus, the greater the rate of spatial
change in E , the greater the gradient force f becomes.
Therefore, an arrangement of the electrodes is considered
that the rate of change in electric field becomes lower in
the vicinity of the substrate and higher in the vicinity of
the electrodes. Such an arrangement allows the substrate
to be acted upon by a greater gradient force f .

More specifically, in a case where the potential of
the vacuum chamber in which the chuck equipment is disposed
is made zero (at the ground potential), an electrode to
which a positive voltage is applied and an electrode to
which a negative voltage is applied may be disposed in
close proximity to each other.

In addition, taking the electric field established
between the electrodes into consideration, with a
dielectric being disposed in the vicinity of the electrodes,
the electric flux is trapped in the dielectric (of relative
dielectric constant $\epsilon_r > 1$). Therefore, the dielectric
disposed between the electrodes of the chuck equipment and
the substrate would cause the electric lines of force to be
readily trapped into the dielectric. Consequently, the
electric field (the density of electric lines of force)
will be made weaker than in a vacuum between the substrate
and the electrodes.

Therefore, contrary to this, such a configuration

with no dielectric being disposed on the electrodes would allow the grad (E^2) to become greater, thereby making it possible to provide a greater electrostatic pressure (gradient force f).

5 The electrostatic pressures acting upon the insulating substrate 83 were measured with the dielectric layer being disposed and with the dielectric layer being not disposed on the electrodes 81, 82 to which the positive and negative voltages are applied as shown in Fig.8.

10 The electrodes 81, 82 are 4mm in width, the distance between the electrodes 81 and 82 is 1mm, and the holding area is 8 inches in diameter. The dielectric employed for comparison is a ceramic comprising Al_2O_3 as a main ingredient, a thickness of 500 micrometers, and a volume
15 resistivity of approximately $10^{11} \Omega \cdot cm$.

A target to be held is a substrate formed of transparent quartz glass having a thickness of 5mm, diameter of 8 inches, a volume resistivity $10 \times 10^{18} \Omega \cdot cm$, and a relative dielectric constant 3.70 (0 to 1 MHz).

20 The measurements of the electrostatic pressure are shown in Table 1 below. When no dielectric is interposed between the substrate and the electrodes 81, 82, the electrostatic pressure increases by approximately 1.5 times.

Table 1: Result of measurements of the electrostatic pressure

Applied voltage (v)	Electrostatic pressure (gf/cm ²)	
	With dielectric layer	No dielectric layer
3 0 0 0	1 5 0	2 3 0
5 0 0 0	3 0 0	4 5 0
8 0 0 0	3 6 0	5 2 0

The base employed for the chuck equipment according to the present invention may be formed of an insulating plate, or a metal plate on which an insulating film is formed with a first and second electrode arranged on the insulating film. The insulating film may be formed of a material such as aluminum oxide, aluminum nitride, silicon carbide, SIALON, diamond, polyimide, and silicone rubber.

In a case where the vacuum chamber for accommodating the chuck equipment therein is connected to the ground potential, the power supply for applying voltages to the first and second electrodes may be adapted to apply a positive voltage to any one of the first and second electrodes and a negative voltage to the other electrode.

Now, an embodiment of a vacuum processing apparatus according to the present invention is shown in Fig.1(a), which is generally denoted at reference numeral 70.

The vacuum processing apparatus 70 comprises a vacuum

chamber 72, a chuck equipment power supply 73, a sputter power supply 75, and a controller (computer) 74 for use with the chuck equipment power supply 73 and the sputter power supply 75.

5 Inside the vacuum chamber 72, there are arranged a sputtering target 76 and a chuck equipment 1 according to a first embodiment of the present invention. Fig.2(a) is a plane view illustrating the chuck equipment 1 and Fig.2(b) is a cross-sectional view taken along line A-A of Fig.2(a).

10 The chuck equipment 1 has a plate-shaped base 10. The base 10 comprises a metal plate 18 and an insulator 19 arranged on a surface of the metal plate 18. The insulator 19 is formed of a layer of insulating ceramic such as aluminum oxide. On a surface of the insulator 19, there are provided first and second electrodes 11, 12 formed of a conductive carbon material. Accordingly, the surfaces of the first and second electrodes 11, 12 protrude from the surface of the base 10.

20 The first and second electrodes 11, 12 are patterned in a comb-shaped configuration, being so arranged as to allow the teeth of the comb to mate in non-contact with each other.

25 The base 10 is 8 inches in diameter, the first and second electrodes 11, 12 are 4mm in width, and the distance between the electrodes is 1mm.

In a case where vacuum processing treatments are performed using the vacuum processing apparatus 70 configured as such, the vacuum chamber 72 is first pumped down to a vacuum and then a substrate is transferred into the vacuum chamber 72 using a substrate transfer mechanism (not shown) to allow the substrate to be placed on the surface of the chuck equipment 1.

Fig.1(b) is an enlarged view of part of the chuck equipment 1, reference numeral 27 designating an insulating substrate placed on the chuck equipment 1.

The placement of the insulating substrate 27 on the chuck equipment 1 allows the back surface of the substrate 27 to be brought into contact with the surfaces of the first and second electrodes. Under this condition, the back surface of the substrate 27 is spaced apart from the surface of the insulator 19, thus forming a gap therebetween.

There is arranged an annular protective plate 9 around the chuck equipment 1. The placement of the substrate 27 on the chuck equipment 1 causes the outer peripheral portion of the substrate 27 to be brought into contact with the inner peripheral surface of the protective plate 9. Moreover, the gap formed between the back surface of the substrate 27 and the insulator 19 is sealed with the protective plate 9.

10 or on the back surface of the base 10 would make it possible to form a thin film while the temperature of the substrate 27 is being well controlled.

In addition, the protective plate 9 provided around the substrate 27 will prevent the plasma formed in the vacuum chamber 72 at the time of sputtering from going into the gap between the back surface of the substrate 27 and the base 10. Thus, no plasma will be present between the first electrode 11 and the second electrode 12, never developing a short-circuit between the first and second electrodes by plasma.

Fig.3(a) is a schematic cross-sectional view illustrating the chuck equipment 1 according to the first embodiment. The chuck equipment 1 has the first and second electrodes 11, 12 formed on the insulator 19, and thus the surfaces of the first and second electrodes 11, 12 are higher than the surface of the insulator 19.

Figs.3(b) to (d) illustrate chuck equipments 2 to 4 according to second to fourth embodiments, respectively.

The chuck equipments 2 to 4 according to the second to fourth embodiments have metal plates 28, 38, 48, respectively.

There is arranged an insulator 29, 39, 49 on each metal plate 28, 38, 48. On the surface of the insulator 29, 39, 49, there is formed a concavity portion 26, 36, 46 such

that the bottom portion thereof will not reach the metal plate 28, 38, 48.

Inside the concavity portion 26, 36, 46 of each insulator 29, 39, 49, there are arranged first and second electrodes 21, 22, 31, 32, 41, 42 being insulated from each other. The lower end portions of the first and second electrodes 21, 22, 31, 32, 41, 42 are arranged on the bottom portions of each concavity portion 26, 36, 46.

In the chuck equipment 2 according to the second embodiment shown in Fig.3(b), the upper end portions of the first and second electrodes 21, 22 protrude from the insulator 29.

Like the chuck equipment 1 according to the first embodiment, in the chuck equipment 2 according to the second embodiment, when the substrate is held against the chuck equipment 2, the back surface of the substrate is placed onto the upper end portions of the first and second electrodes 21, 22 and a gap will also be formed between the back surface of the substrate and the insulator 29.

In the chuck equipment 3 according to the third embodiment shown in Fig.3(c), the upper end portions of the first and second electrodes 31, 32 are formed flush with the surface of the insulator 39. That is, the surface of the insulator 39 is formed flush with the upper end portions of the first and second electrodes 31, 32. When a

substrate is held against the chuck equipment 3, the back surface of the substrate is brought into contact with the surfaces of the first and second electrodes 31, 32 and the insulator 39.

5 In the chuck equipment 4 according to the fourth embodiment shown in Fig.3(d), the upper end portions of the first and second electrodes 41, 42 are formed below the surface of the insulator 49. That is, the upper end portions of the first and second electrodes 41, 42 are
10 located a little below the surface of the concavity portion 46, and a convexity portion 47 formed of the surface portion of the insulator 49 is formed between the first and second electrodes 41, 42.

In the chuck equipment 4, when a substrate is held
15 against the surface thereof, the back surface of the substrate is brought into contact with the upper end portions of the convexity portion 47 but not brought into contact with the first and second electrodes 41, 42.

Thus, the first and second electrodes 41, 42 are
20 provided with prolonged life since the substrate is brought into contact with the surface of the insulator 49 having high wear resistance but not brought into contact with the first and second electrodes 41, 42 of comparatively low wear resistance.

25 However, to prevent the electrostatic pressure from

being decreased, it is desirable for the convexity portion
47 to protrude 500 micrometers or less from the surfaces of
the first and second electrodes 41, 42.

In addition, a protective film may be formed on the
surfaces of the first and second electrodes 11, 21, 31, 41,
12, 22, 32, 42 to provide the electrodes with prolonged
life in the first to third embodiments of chuck equipments
1 to 3 where the surfaces of the electrodes can be brought
into contact with the back surface of the substrate and
even in the chuck equipment 4 according to the fourth
embodiment. To prevent the electrostatic pressure from
being decreased, the protective film is several tens to
several hundreds of micrometers in thickness and preferably
500 micrometers or less in thickness.

Fig.4(a) is a view illustrating a chuck equipment 5
in which a protective film 16 formed of an insulating thin
film such as a silicon oxide film is formed on the surface
of the chuck equipment 1 according to the first embodiment.
The chuck equipment 5 allows the substrate 27 to be brought
into contact with the protective film 16. The protective
film 16 covers the first and second electrodes 11, 12 and
the surface of the insulator 19 exposed therebetween,
however, no short-circuit is developed between the first
and second electrodes 11, 12 due to the insulating property
of the protective film 16.

On the other hand, in a case where the protective film is conductive, the conductive protective film may be allowed to cover only the upper surfaces of the first and second electrodes or the protective film may be formed so as not to short-circuit the both electrodes. In this case, the first and second electrodes would function as if they were exposed.

Fig.4(b) is a view illustrating a chuck equipment 6 in which a conductive protective film 17 is arranged on the surfaces of and around the first and second electrodes 11, 12 of the chuck equipment 1 according to the first embodiment. The original first and second electrodes 11, 12 and the protective film 17 combine electrically with each other, so that the protective film 17 play the electrodes. Since the conductive protective film 17 is not arranged on the surface of the insulator 19, no short-circuit is developed by the protective film 17 between the first and second electrodes 11, 12.

Fig.4(c) is a view illustrating a chuck equipment 7 in which a conductive protective film 17' is formed on the surfaces of the first and second electrodes 41, 42 in the chuck equipment 4 according to the fourth embodiment. In the chuck equipment 7, the upper surfaces of the fourth embodiment of first and second electrodes 41, 42 are located below the surface of the insulator 49, same as the

chuck equipment of fourth embodiment. In the chuck
 equipment 7, the conductive protective film 17' is formed
 on the surface of the first and second electrodes 41, 42.
 The surface of the conductive protective film 17' is flush
 5 with the surface of the insulator 49 but no short-circuit
 is developed between the first and second electrode 41, 42.

Incidentally, the aforementioned protective films 16,
 17 can be formed by PVD, CVD, or ion implantation. The
 protective films 16, 17 are preferably 500 micrometers or
 10 less in thickness to prevent the electrostatic pressure
 thereof from being decreased.

The chuck equipments 1 to 4 according to the first to
 fourth embodiments have the electrodes patterned in a comb
 configuration, however, the chuck equipment according to
 15 the present invention is not limited thereto.

The chuck equipments 1 to 4 according to the first to
 fourth embodiments can also employ the electrode
 configurations shown in Figs.6(a) to 6(c) and Figs.7 (d)
 and 7(e).

20 A chuck equipment 51 shown in Fig.6(a) has comb-
 shaped first and second electrodes 51₁, 51₂, the comb teeth
 of which are arranged concentrically.

A Chuck equipment 52 shown in Fig.6(b) has eight
 comb-shaped electrode 52A₁, 52A₂, 52B₁, 52B₂, 52C₁, 52C₂,
 25 52D₁, 52D₂ which are divided into first four electrodes 52A₁,

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52B₁, 52C₁, 52D₁ to which the same voltage is applied. A voltage of same magnitude is applied to second four electrodes 52A₂, 52B₂, 52C₂, 52D₂ but the voltage of magnitude applying to second four electrodes 52A₂, 52B₂, 52C₂, 52D₂ is different from the voltage applying to first four electrodes 52A₁, 52B₁, 52C₁, 52D₁. A case in which same absolute value of voltage but the different polarity is included in the case of different magnitude of voltage between first and second electrodes. A case in which one of the first and second electrodes is kept at the ground potential, and positive or negative voltage apply to the other electrode is also included in the above-described case of different magnitude of voltage.

The first four electrodes 52A₁, 52B₁, 52C₁, 52D₁ and the second four electrodes 52A₂, 52B₂, 52C₂, 52D₂ are patterned in a comb configuration with the teeth portion thereof being concentrically formed. The teeth portions of first four electrodes 52A₁, 52B₁, 52C₁, 52D₁ and the second four electrodes 52A₂, 52B₂, 52C₂, 52D₂ are alternately arranged so as to mate in non-contact with one another. These four pairs of electrodes may be applied with voltages of different magnitudes as necessary.

A chuck equipment 53 shown in Fig.6(c) is provided with the first and second electrodes 53₁, 53₂ arranged in a double spiral fashion.

Now, a chuck equipment 54 shown in Fig.7(d) has a surface divided into four regions. On each of the regions, there is arranged a pair of first electrodes 54A₁, 54B₁, 54C₁, 54D₁, patterned in a comb configuration, and second electrodes 54A₂, 54B₂, 54C₂, 54D₂, also patterned in a comb configuration. The teeth of the comb of the first electrodes 54A₁, 54B₁, 54C₁, 54D₁ and the second electrodes 54A₂, 54B₂, 54C₂, 54D₂ are adapted to mate with each other.

In the chuck equipment 54, first four electrodes 54A₁, 54B₁, 54C₁, 54D₁ are applied the same voltage. A voltage of same magnitude is applied to second four electrodes 54A₂, 54B₂, 54C₂, 54D₂ but the voltage of magnitude applying to second four electrodes 54A₂, 54B₂, 54C₂, 54D₂ is different from the voltage applying to first four electrodes 54A₁, 54B₁, 54C₁, 54D₁. A case in which same absolute value of voltage but the different polarity is included in the case of different magnitude of voltage between first and second electrodes. A case in which one of the first and second electrodes is kept at the ground potential, and positive or negative voltage apply to the other electrode is also included in the above-described case of different magnitude of voltage. The voltages applied to the four pairs of electrodes can be changed as necessary to provide a higher voltage to the portion whose electrostatic pressure is desirably increased.

